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15 November 1961

MEMORANDUM FOR: Chief, TP&DS

THROUGH: Chief, TID

25X1 FROM: [redacted]

SUBJECT: Staff Study--Selection of a Computing System for Use by the Technical Intelligence Division, NPIC

1. PROBLEM

The present TID computing system functions primarily as an element of the TID system for answering photo-analyst requests for dimensional and positional information about objects and points imaged on photography. Even under the current operations of the Center a modest increase in the number of measuring machines in use in TID could give rise to peak load situations (i.e. during OAK and MCI exploitation of [redacted] missions) where-in the present Alwac computer would fall seriously behind in reducing these requests. Additionally certain desirable extensions of the present computer operation such as the use of more sophisicated mathematical models and the automatic production of coverage plots from orbital information are not presently feasible with our current computing equipment. The problem thus arises of selecting a computing system adequate to the projected role of NPIC. 25X1

2. ASSUMPTIONS

The "lead time" on the delivery of the actual hardware of a computer system is generally on the order of one to two years, with the same figure holding for the associated programming effort (which procedes concurrently with the construction and delivery of the hardware). Since it is at least reasonable to hope that a system can be so chosen as to satisfy our requirements over a five year period, we must make certain basic assumptions as to the amount and nature of the photographic coverage that will be input to the Center. Specifically we assume that:

A. The rate of input of photography collected from orbital vehicles will continue to increase.

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B. The scale and quality of such photography will continue to increase.

C. All future collection systems that will have any significant impact upon the Center will be so instrumented that the spacial position and orientation of the camera for each exposure will be known either by the time the film is delivered to NPIC or, in the worst case, will become available as the first scan of the film is carried out.

D. In staffing, the presently projected increases in the number of photo-analysts assigned to NPIC will indeed come to pass. Further these figures must be taken as a lower limit when projected to the end of the six-year period.

3. FACTS

The most notable deficiency of the present Alwac-centered photo-measurement system is that it cannot respond with sufficient rapidity to requests levied against it by the photo-interpreters. This deficiency is discussed in more detail in the annex to this paper entitled "A PHOTO-MEASUREMENT SYSTEM FOR USE IN NPIC."

4. DISCUSSION

The mere introduction of new computing equipment, however fast and on whatever scale, into the present photo-measurement system will not effect any substantial correction of the deficiency mentioned in 3, since this deficiency stems far more from the procedures followed than the capabilities of the various machines (computer, measuring engines) used in implementing those procedures. Consequently it has been taken as a premise that the following basic change in photo-measurement procedures will be made:

> The photo-analyst will have personal, direct, and immediate access to the photo-measurement system, and the system will make its responses directly to the analyst.

A more detailed description of the operation of such a system is given in the annex. It should be noted that the effective operation of the system is predicated upon our Assumption C of this study. Further it should be remarked that this change in procedure does not preclude the use of present procedures in those cases where such is desirable from the photo analysts view or more efficient from an overall view.

From the premise that the computing system chosen for use in this division will function as an element of a real-time photo-measurement system three gross criteria are evolved as indicated in the annex. In consultation

X1 with [redacted] and bearing in mind the balance of the assumptions of 2, a more detailed set of specifications were developed from the gross criteria and the entire list of commercially available digital computers evaluated against these criteria. The criteria and details of the evaluation are
X1 given in the [redacted] report, "A SCIENTIFIC COMPUTER - CRITERIA, EVALUATION and SELECTION."

5. CONCLUSIONS AND RECOMMENDATIONS

It was concluded in the above-mentioned report that a UNIVAC 490 computing system is the most suitable for use as the computer element of a real-time photo-measurement system. The exact configuration of the computer is still under study but will include at least the following:

1. Central computer with 16,384 words of core memory
2. Hugh-speed printer
3. FH-880 Magnetic Drum
4. Four Uniservo IIA Magnetic Tape Units
5. Card reader and punch
6. Paper tape reader and punch
7. Random access storage device
8. Control and synchronization equipment for items 2-6 above
9. Certain "communications interface" equipment for tying in the remote stations.

Rental of the above equipment will be approximately [redacted] per month. 25X

It is recommended that a decision be made to implement a computer centered real-time photo-measurement system and that as an initial step in
this implementation a letter of intent to [redacted] for the 25X
rental of a 490 system of the approximate configuration given above be issued.

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Attachment:
A Photo-Measurement System for Use in NPIC

Distribution:
Original - Chief, TP&DS (w/3 cys of attachment)
1 - Chief, TID (w/1 cy of attachment)
X1 1 - [redacted] w/1 cy of attachment)

X1 NPIC/TID: [redacted] dbg (16 Nov 61)

A PHOTO-MEASUREMENT SYSTEM
FOR USE IN NPIC

I. The General Nature of the Photo-Measurement Problem

Technical Intelligence Division has as one of its basic responsibilities the support task of providing the PI analyst with distance determinations between points imaged on photography or with the equipment and operating procedure to effect such determinations himself if he so chooses. It is in attempting to fulfill this basic responsibility that the TID requirement for a digital computer arises. To explain the current operations on the TID ALWAC III-E computer, the inadequacy of the present facility for anticipated future operations, and the criteria used in the design of the proposed photo measurement system and in the selection of the digital computer element, it is first necessary to consider the principle approaches that might be made to the problem.

The determination of distances from a photo (or photographs) is, in the most general sense, accomplished by creating a model of the situation that existed when the photography was taken and performing measurements on that model. The model can be either analog or mathematical. Examples of analog models are:

1. The photograph itself, in the case of a vertical photograph.
2. The stereo image in an optical-mechanical plotting instrument such as the [redacted] A-5 plotter or the [redacted] plotter.
3. The particular circuitry and state of an optical-electronic device such as the [redacted] Measuring Viewer.

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The mathematical model is, of course, a set of functional expressions in several parameters that can be regarded as describing a type of camera system and the relation of the image that it forms to the scene that it photographs. In this type of model points on the photograph are represented by coordinates in the plane of the photograph. Specifying particular values for the parameters referred to above (such as focal length, position and orientation of the camera during exposure) establishes the skeleton, so to speak, for the model of a particular frame of photography. The skeletal structure is then filled out by supplying the coordinates of the points with which the analyst is concerned.

The principal weaknesses in the actual application of the analog approach arise from the physical limitations and imprecisions of the hardware necessary. For example, a C-8 stereoplanigraph is engineered for flat-film-plane photography of a particular focal length, an optical rectifier necessarily rectified to a flat earth, the [redacted] Measurement Viewer is limited 25X
in accuracy by the inherent imprecision of electronic analog circuitry.

For actual realization of the mathematical approach the requirements are a photo-coordinate measurement device and a computational procedure derived from the mathematical model. Changes in the mathematical model or in the values of any of the parameters of that model are at most changes in the computational procedure rather than in the hardware involved. The problem arises, however, that for even relatively simple models (such as a conventional oblique photograph) the computational procedure for a single measurement is far too lengthy to be performed manually (on a desk calculator). The computational problem is met in this approach by use of an electronic digital computer, with the computational procedure now represented by a stored program for the computer. Clearly, changes in the mathematical model (for example to accommodate unconventional photographic systems) are evidenced as additions to the library of programs for the computer, and no changes in the system hardware are required.

This property of the mathematical model procedure (i.e., that it can be changed without requiring changes in the hardware) was the basis for the TID decision to follow this procedure, a decision that seems particularly appropriate when considered against the background of a range of photographic collection systems of widely varying characteristics whose development often outpaces development of special purpose exploitation equipments. Major changes from one type of camera system to another (say from a conventional flat-film-plane system to a sweep panoramic system) will usually require a new program (or set of programs) but changes of specifications within any general type (say, focal length or format dimensions) which might require completely new special purpose equipment merely mean that computer reduction of photography from the new system employs different values for the particular parameters involved in the mathematical model. There is one hardware restriction of a very general nature that can be stated as follows: The photo-coordinate measurement device must be able to measure in a photo-coordinate system rather than merely in an arbitrarily chosen coordinate system on the film. Practically, this means that the measurement device must be able to measure over the entire format (including fiducial marks if present) of the photographic record.

II. The Present NPIC Computer-Centered Measurement System

A system with the logical characteristics just described has been realized by TID in the [redacted] Comparator - Alwac computer combination. That this system does not satisfy current or anticipated NPIC photo-measurement requirements is due, in the most general sense, to problems of communication to the system and within the system. Communication within the system is, at best, indirect and only semi-automatic. Once the cross-wires of the measurement device are positioned over a selected point, the operator can initiate an automatic read-out of the photo-coordinates of that point in a form that can be directly read by the computer (i.e. punched tape) but the actual transfer of the information to the computer is manual. That is, the tape must be physically transported to the computer area, the computer operator must manually select and initiate (i.e. load the appropriate program into the computer if it is not already in storage, and call that program into control of the computer), the programs that will load the coordinate data into the computer and provide for the reduction of this data to meet the photo-analyst's needs. Additionally, the computer operator must provide as supplemental manual inputs to the program the parameters that describe or specify the particular frame of photography from which the coordinates were measured. One consequence of the presence of these "manual" communication elements within the current system is that the efficiency of the system is inversely proportional to the number of points being handled per photograph. Thus the present Alwac-centered system functions very efficiently for, say, producing a dimensioned lay-out of a large industrial complex containing two or three hundred structures--and it operates very inefficiently for such tasks as checking one or two distances in a SAM Site or obtaining the length of a runway. It is precisely this latter type of measurement that is of highest (metric) significance to the analyst in his photo-interpretation process. These are the "working" measurements of the photo-interpreter which he uses, in varying degree, to guide his interpretation by supplying confirmation, denial, or plausibility to many of the tentative working hypotheses that he is constantly (though perhaps unconsciously) formulating as he studies the photography. To describe this class of measurements in another way they can be characterized as being the measurements which, for conventional vertical photography, were obtained with boxwood scale or tube magnifier and reduced with a single multiplication on a slide rule. (It might be remarked that one of the design goals for any photo-measurement system should be that it be as simple and easy for the analyst to use as are his methods for dealing with conventional vertical photo cover.)

It is estimated that 75 to 90 percent of the measurement requirements that arise within the Center fall in the category just described. That the presently operating system does practically nothing toward satisfying these requirements stems, not directly from the inefficiency of applying a "batch" type reduction process to these problems, but rather to the fact that the system cannot respond to this type of request in a sufficiently timely manner for it to be of any use to the photo analyst. That a sufficiently rapid response cannot be achieved results from the problems of communication between the analyst and the photo-measurement system. These problems can be further categorized as (1) problems of transmission rate, and (2) semantic problems.

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The nature of the transmission rate problem can be best shown by considering a typical requirement for measurement that might arise. Suppose that the photo-analyst is attempting to categorize a particular submarine under construction in a shipyard. He will desire at least such dimensions as overall length, length of the sail, and the distance from bow to sail. To obtain these measurements from TID the analyst must convey at least the following information to TID:

1. His own identity (this is so basic an item of information that its inclusion in this list may seem absurd - but there must be explicit provision for this in a more automatic system), in order that the answer be returned to him.
2. The accession number of the photograph (i.e., mission and frame).
3. The location of the target on the frame (Perhaps indicated by a grid referencing or perhaps merely by circling with a grease pencil on a paper print).
4. The particular points of the target that are to be taken as the endpoints of the segments to be measured. (Frequently this information is conveyed by a written description or indicated on a rough sketch of the target).

When this information has been duly recorded in documentary form (a process which may require several minutes) and transmitted through the proper channels (which may require some hours or even days) to TID, the TID analyst must perform the following operations:

1. Obtain a copy of the frame referenced in the request.
2. Place the frame in the measuring machine and establish the relation of the photo-coordinate system to the machine coordinate system.
3. Determine the measuring machine coordinates of the points indicated in item 4 of the photo-analyst's request.

It is quite obvious from the description that the current system cannot provide the photo-analyst with distance determinations as his need for them arises. In actual operation the minimum response time is about 30 minutes and is rarely attained. A further weakness in the system occurs in operation (3), above. This already has been aluded to as the semantic problem and consists quite simply of the fact that no description, sketch, or other device, can convey to the measuring machine operator the precise location of a point that the photo-analyst has in mind. In other words what the photo-analyst wants is the distance between two points that are of some significance in his interpretation of what he sees, and the TID measuring machine operator's identification of these points depends upon his reproducing to some approximation, the analyst's interpretation. The degree of approximation permitted the measuring machine operator is determined by the precision of the measuring machine itself, the scale and quality of the imagery, and the absolute accuracy needed by the photo-analyst -- a discrepancy of twenty feet (on the ground) between two interpretations of the extent of an airfield runway is of no consequence what-so-ever; the same variance on the distance from sail to bow of a newly observed submarine can be a serious and substantial problem. Actual experience with the present system has been that for critical measurements involving a question of "pointing" there is often a sequence of requests (from the photo-analyst) for redetermination of the distances, and that the comparator operator terminates this sequence only by inviting the photo-analyst to position the cross-wires on the image to his own satisfaction.

III. A Real-Time Photo-Measurement System

The system now proposed for photo-measurement use will overcome the deficiencies of the present comparator-computer (with associated operators) system by eliminating certain communications channels and speeding up others. The speeding-up of communications will, in general, be effected by substituting machine communication functions for human operator communication functions. We will begin our description of the system by regarding it as a "black box". That is, we will describe it first as it appears to the user of the system, who is concerned, not with its inner workings, but rather with his actions (i.e. "inputs") in relation to the system and the responses the system makes to those actions.

The analyst will observe the images of concern on some device that incorporates a measuring machine capability. (The terminology of the last sentence is deliberately vague since the detailed specifications of the nature of such devices involves far more than just their logical compatibility with the balance of the photo-measurement system, for which they serve, possibly inter alia, as input devices. We must, however, point out that much of the effectiveness and utility of the photo-measurement system will depend directly on the <u>overall</u> performance of whatever equipment provides the coordinate input.) Directly adjacent to the viewing equipment (or possibly incorporated into it as an integral part of the hardware) will be, minimally, a keyboard, printer, and several illuminated push buttons. Desiring to make several measurements on a particular frame, the analyst turns on the keyboard printer and types the mission number and frame number. (He may also type his name and the number of the project that he working on. This information would be used by the system for record-keeping purposes). He then centers the cross-hairs of the measurement device over one of the fiducial markers of the frame under study and depresses a foot-switch. He then does the same for the opposite fiducial. Next he indicates what general type of measurement he desires by pressing the appropriate momentary contact switch. For illustration we assume that the "general type" is "GROUND DISTANCES BETWEEN SUCCESSIVE PAIRS OF POINTS". He then positions the cross-hairs at one endpoint of the first segment to be measured and depresses the footswitch. The same process is repeated for the other endpoint of the segment. Within a fraction of a second the printer will begin outputing the ground distance between the two points together with a figure giving probable error. The analyst may type any additional identifying data or comments, or he may proceed to the first point of the next pair as soon as he has depressed the footswitch. Continuing in this manner he obtains his desired distances. If he desires to switch to some other "general type" of metric operation he has only to depress the appropriate pushbutton. Thus he might, for example, have height determinations on the antennae in an antenna farm intermixed with the distances between the antennae, and might simultaneously be producing a rectified map overlay plot of the layout of the array.

The description just given has been in terms of one analyst and the "PHOTO-MEASUREMENT SYSTEM" but is to be understood as holding for any number of analysts engaged in simultaneous operation against the system.

We now turn from our black-box description (which might, equivalently, have been termed "a set of specifications for the design of the system") of the "external properties" of a photo-measurement system to a consideration of the characteristics required of the various components in order to achieve the overall system operation that has been described. The system has as its central element a general-purpose digital computer system that must satisfy the following criteria:

1. The computer system must be able to accept communications from external sources (i.e. from the remote coordinate measurement devices, keyboards, pushbuttons, and possibly such other devices as light pencils, etc.) at times and intervals determined only by the external source rather than by the computer. Specialized to current computer hardware this requirement means that the computer have an "interrupt" capability and buffered input and output.

2. The computer system must have the "photo parameters" for each frame in the collection available in a fraction of a second. The time requirement dictates that this file of information be kept in the auxilary memory of the computer system; taken with the random ordering of requests against the file the time limitation requires that the auxilary storage be of the type generally termed "random-access memory". This ordinarily means a rotating memory device, either large capacity drum or multiple disk unit, in contrast to serially accessible memory such as magnetic tape.

3. The most elemental and obvious criteria for the computer system is also the most difficult to state with precision. We can state tautologically that the computer must be sufficiently fast for real-time system operation. For this application the speed required of the main frame of the computer system is determined, not by the total amount of actual arithmetic computation that might be required per hour, but rather, by the real-time requirement that the results from any particular set of inputs data be available within a very short interval after the input has been completed. To explain, even very generally, the nature of this dependence we must give some consideration to the internal operation of the computer system. The interrupt capability, referenced in (1) above, operates in the following manner:

An interrupt signal can arrive at the computer from any one of several different external sources. When the signal is sensed by the computer the following events take place:

a. The computer finishes executing its current instruction.
b. The computer goes to a fixed location for its next instruction, without, however, changing the contents of its current-instruction-location register. There is a different fixed location to correspond to each interrupt source (an "interrupt source" from the computer's viewpoint is simply the particular circuitry through which the signal arrives.)

The preceding is all of the computer reaction to an interrupt signal that can be attributed directly to the "hardware" of the computer. (There is, however, one other aspect of the hardware that is relevant to our discussion--there are commands available to the programmer to inhibit the response just described.) The balance of our description is in terms of programmed actions.

c. The sequence of instructions beginning in the interrupt location (i.e. the "fixed" location of the preceding step) will ordinarily begin by storing the contents of the current-instruction-location register (which was left unchanged in step b). In animistic terms the computer will remember what it was doing when it was interrupted. Additionally, the interrupt capability will be locked-out at this point to prevent a new interrupt from the same source (which would cause the computer to "forget" where it was at the time of the first interrupt).

d. Ordinarily the external interrupt signal does not, in itself, convey sufficient information to completely determine the computer's course of action. Consequently the next programmed action must provide for the computer to accept sufficient further input to enable it to identify (by a programmed analysis, of course) the "ultimate" source of the interrupt signal and the particular actions that must be taken to handle the remainder of the inputs that will be transmitted by that source as data for the problem it is handling.

We may summarize the preceding description by saying that the interrupt capability of a computer system consists of:

1. The hardware interrupt feature (which, though essential, can be characterized as permissive)

2. The logically complex program which provides overall direction to the operation of the computer (even to the extent that normal computer-operator actions are effected only at the discretion of, and under the control of, this program), ordinarily referred to as the EXECUTIVE or MONITOR program.

It is now obvious that for the computer component to function in a real-time manner it must be able to perform the desired arithmetic operations <u>and</u> all the EXECUTIVE operations that would be required under a maximum load against the system within the time limits set. It is estimated that a computer with an access time (to its core memory) of six microseconds should be able to perform the task proposed and have every considerable capability for system expansion. The actual machine time used in processing the real-time measurement application will be only a very small percentage of the total time available per shift. (This is, obviously, characteristic of all real-time computer systems.) The balance of the time is available for running ordinary batch-type production programs under the control of the EXECUTIVE PROGRAM.

The balance of this photo-measurement system is the collection of "remote stations" at which the analysts perform their measurements and communicate with the computer and receive information from the computer. The logical requirements on the measurement device have already been mentioned and the importance of proper design from the user's viewpoint stressed. Of equal importance is the design and realization of the equipment for direct two-way communication between the photo-analyst and the computer. The references to typer and keyboard in the "black-box" description of system operation were necessary to give a concrete illustration of the functioning of the system but should not be taken as excluding such forms of communication as alpha-numeric and graphical CRT displays, light pencils, and even audio responses by the computer system. All possible means of man-computer communication should be considered to arrive at a system having the maximum possible ease, simplicity and flexibility of operation for the real user of the system, the photo-analyst.